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GROUND WATER - WHY WORRY?

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MANAGEMENT PERSPECTIVE

Twenty-six percent of Canadians use ground water for their domestic supply but problems associated with this resource have received much less attention than that of surface water. Even less appreciated is the influence of ground water on surface water quantity and quality. Ground Water is the single most important parameter in several contaminant studies which originally started as studies of such surface water problems as acid rain, radioactive waste disposal, Niagara River pollution, etc. In this context, the two general misperceptions about ground water: one that it stays underground, and two, that its chemistry is relatively unchanging, are refuted. With regard to ground water monitoring programs and in particular in Northern Canada the primary consideration is that such programs should be targeted towards specific issues or problems. Finally, the price of ignoring ground water in the short term is great expense in the long term.

PERSPECTIVE DE GESTION

Vingt-six pour cent des Canadiens utilisent des eaux souterraines pour leurs besoins domestiques, mais les problèmes associés à cette source attirent beaucoup moins l'attention que dans le cas des eaux de surface. Et on se rend encore moins compte des effets de l'eau souterraine sur la quantité et la qualité des eaux de surface. Les eaux souterraines sont le paramètre unique le plus important dans plusieurs études de contaminants qui, au départ, étaient des études sur les problèmes des eaux de surface tels que la pluie acide, l'élimination des déchets radioactifs, la pollution de la rivière Niagara, etc. Dans ce contexte, les deux idées générales relatives à l'eau souterraine: qu'elle reste sous terre et que sa composition chimique reste relativement inchangée, sont réfutées. En ce qui concerne les programmes de surveillance de l'eau souterraine, en particulier dans le nord du Canada, il faut avant tout veiller à ce que ces programmes portent sur des questions ou des problèmes précis. Finalement, le fait d'ignorer l'eau souterraine à court terme aura des répercussions néfastes à long terme.

ABSTRACT

On a national basis, on average, 26% of Canadians use ground water for their domestic supply. The quality of this ground water is obviously of direct concern to users. It is not as well appreciated that ground water also has a very important effect on surface water quality. This is because the ground water contribution is not obvious to casual observation. There are two general perceptions about ground water: one, that it stays underground, and two, that its chemistry is relatively unchanging. Both of these beliefs are untrue. In studying ground water, several physical and chemical factors must be taken into consideration, including permafrost as a special consideration in Northern Canada. In establishing a monitoring program to investigate the physical and chemical properties of ground water, the major concern is to design the program to resolve specific problems. The most effective solution to ground water contamination problems is to prevent them from happening in the first place. Where this is not possible action to restrict the spread of contamination must be taken as quickly as possible. The least acceptable alternative is to ignore the issue in the hopes that it will go away.

RESUME

A l'échelle nationale, 26 p. 100 des Canadiens en moyenne utilisent les eaux souterraines pour leurs besoins domestiques. Il est évident que la qualité de cette eau souterraine concerne directement les utilisateurs. On ne se rend pas bien compte que l'eau souterraine a de plus un effet très important sur la qualité des eaux de surface. Cela est dû au fait que la contribution des eaux souterraines n'est pas évidente lorsqu'on fait des observations occasionnelles. Il y a deux idées générales au sujet de l'eau souterraine: qu'elle reste sous terre et que sa composition chimique reste relativement inchangée. Ces deux croyances sont fausses. Lorsqu'on étudie l'eau souterraine, il faut tenir compte de plusieurs facteurs physiques et chimiques, notamment le pergélisol dont il faut spécialement tenir compte dans le nord du Canada. En mettant sur pied un programme de surveillance en vue d'étudier les propriétés physiques et chimiques des eaux souterraines, il faut avant tout s'efforcer de concevoir le programme de façon à résoudre des problèmes bien précis. La solution la plus efficace au problème de contamination des eaux souterraines est d'empêcher cette contamination en premier lieu. Lorsque ce n'est pas possible, il faut prendre des mesures aussitôt que possible pour éviter que la contamination ne se répande. La solution la moins acceptable est d'ignorer ce problème en espérant qu'il disparaîtra.

GROUNDWATER - WHY WORRY?

INTRODUCTION

The study of ground water has taken on increased importance in Canada over the last decade, particularly in the South. Ground water sources make up a significant, and in some locations an all important, percentage of all water used. As a national average, 26% of Canadians use ground water for their domestic supply, and approximately 38% of municipalities rely entirely or partially on ground water (Hess, 1986). By province, the percentage of the population relying on ground water varies from 17% in Quebec to 100% in Prince Edward Island (Hess, 1986). The quality of ground water, then, is obviously of direct concern when assessing the suitability of sub-surface water supplies for various uses.

The fact that ground water often has a very important effect on surface water quality, however, is less well understood. The contamination of the Niagara River by ground water which contains pollutants from leaking chemical dumps, or the mitigation by more basic ground water of the effects of acidic precipitation on surface water acidification (Craig and Johnston, 1987) are pertinent examples. These two cases illustrate the fact that the contribution of ground water is not obvious to casual observation; unfortunately the old dictum "out of sight - out of mind" is only too true. It seems to be a quirk of human nature that we do indeed

tend to forget about what we cannot see with our own eyes. Perhaps this is why we have a habit of putting garbage dumps in old gravel pits: the leachate drains away very nicely with the ground water instead of lying about on the surface offending our sensibilities.

But if ground water is out of sight, why should we worry about it? The first and most obvious reason is that ground water is used as a source of water supply and that if the ground water were to become contaminated a very valuable resource would be lost. The second and often more important reason arises from what might be called the second law of ground water flow: that is, "what goes down must come back up eventually". This law means that every litre of water entering the ground water mass from the surface sooner or later comes back to the surface. It may then discharge into a stream, a lake, or a swamp, or it may just reach the root zone and be transpired without any obvious indication that ground water discharge is occurring. The implication in all of this is that whatever lies in the discharge area will be affected by the quality of the discharging ground water. It is therefore no more than the truth to say that "today's ground water is tomorrow's surface water" and that the health of the ground water system directly affects the health of the surface water environment.

From a different point of view, that of resource management, it is often argued that "there are no fish in ground water" and that therefore it is not necessary to protect the ground water resource in order to protect the fishery resources. However, the opposite is more often true, given that much of today's surface water is yesterday's ground water. If water has been contaminated in its underground domain it will very likely still be contaminated when it becomes surface water inhabited by fish. In addition, many fish hatchery owners prefer ground water for their hatcheries, and therefore many fish now living in other waters have been raised on ground water.

The types of interaction between ground water and surface water are numerous (Figure 1). The nature of the interactions depends on the pathways water travels as it makes its round through the hydrologic cycle from precipitation to surface water. Generally speaking, water in the form of precipitation falls on a land surface, infiltrates into any overburden present, moves underground for a time period varying from minutes to centuries, and then emerges into a surface water body (stream, river or lake). The net result is a change in chemistry. In an undisturbed environment, the chemistry of the precipitation is first modified by any vegetation, then further modified in the subsurface environment by the overburden or rock with which the water comes in contact. If the water also encounters sources of contaminants along its flow path, these too will be added to the ground water and subsequently to the surface water. This usually results in poorer surface water

quality. In the case of acidic precipitation, however, ground water discharge may act to improve the quality of the surface water by supplying more alkaline water to counteract the acidifying properties of the precipitation. Because the types of subsurface reactions and flow paths are numerous and complex, and because the subsequent effects on the surface water quality are so various, detailed knowledge of the particular flow path and of the specific reactions occurring in the subsurface is essential in order to predict the final impact on surface water quality.

PROBLEMS IN THE STUDY OF GROUND WATER QUALITY

In the study of ground water, several factors must be taken into consideration. The nature of the aquifer exerts a profound influence on both the physics and the chemistry of the ground water regime. The flow is dictated by the physical properties of the aquifer material, such as grain size, grain shape, degree of sorting, degree of weathering, porosity, permeability and degree of compaction. The chemical reactions are controlled by the mineralogy, the available surface area, the amount of weathering, and by the reaction time, which is in turn controlled by the flow characteristics. The period of contact between water and soils or rock also determines the degree to which these reactions will approach equilibrium.

The flow regime is influenced not only by the nature of the aquifer but also by the hydraulic gradient. Other factors being equal, ground water will flow more quickly in areas of high relief than under broad, flat terrain. The consequences in terms of the speed of contaminant movement and the potential for interaction are evident.

The initial chemistry of precipitation or throughfall also plays a part in determining ground water chemistry. The transport of acidic precipitation or toxic chemicals through the atmosphere and their subsequent deposition, for example, have a significant effect on ground water chemistry. Higher acidity results in greater amounts of acid neutralizing species being brought into solution and will result in their eventual disappearance from the aquifer. Increased leaching of heavy metals and aluminum from the aquifer materials is also a result of these reactions, and one which has serious implications for the health of plants and animals. With a long enough flow path, and therefore a long time underground, many of these contaminants will not reach the surface for a long time. Even with a long flow path, however, the ground water system will eventually be unable to cope with the load and breakthrough will occur.

In studies of ground water in Northern Canada an additional consideration must be introduced -- permafrost. In some circles the perception persists that permafrost constitutes a impermeable barrier which prevents ground water flow. In fact, ground water does move through permafrost in

one way or another (Shepelev, 1983). Furthermore, the ground water moves in different ways in zones of continuous and discontinuous permafrost. The questions associated with the physical properties of ground water in permafrost regions have been addressed by several authors (Pewe, 1983), but many questions remain to be answered. The chemical reactions, for example, both those that occur naturally and those that involve man-made contaminants, have received far less attention than the physical aspects. In particular, little is known of how these reactions are affected by temperature variations and periodic freeze-thaw cycles.

THE ROLE OF GROUND WATER IN WATER QUALITY PROBLEMS

There are two general perceptions about ground water: one, that it stays underground, and two, that its chemistry is relatively unchanging. These have led to a general impression that ground water quality and quantity are unimportant in the general scheme of things, especially when compared with surface water quality and quantity.

Ground water, however, is the single most important parameter in several contaminant studies which originally started as studies of such surface water problems as acid rain (LRTAP), radioactive waste disposal, Niagara River pollution, leaking underground storage tanks (LUST), and various spills.

In the case of acid rain, ground water was initially considered unimportant to the overall picture, and was assigned the status of a black box to balance the hydrologic cycle (Jefferies, 1982). In most LRTAP (Long Range Transport of Airborne Pollutants) studies, the aquifer-ground water system is now considered to be the controlling factor in determining whether a surface water body will become acidified or not. The presence or absence of overburden, a measure of the carbonate content, and a measure of its permeability are now included in most models used to predict basin acidification (Cosby, 1985).

In the high level radioactive waste disposal program ground water is considered both a resource to be protected, and by far the most likely pathway for radionuclides to escape to the biosphere if the engineered containment measures were to fail. The search for a disposal site has involved locating an unfractured granitic pluton where little or no ground water is present and where any flow is extremely slow. Within the vault used for storage, the containers would be engineered to withstand attack by any ground water which might enter. In case of a container failure, the ground water flow path must be of sufficient length to contain the waste until it is no longer hazardous. While all of the objectives of the waste disposal program have not yet been met, ground water has played, and will continue to play, a crucial role in determining the viability of the program.

It is not necessary to discuss in detail in this paper other examples of the chemical interactions between ground water and surface water. It is enough to say that these interactions further illustrate actual and potential cases of surface water contamination through the intermediary of ground water.

While the chemical properties of ground water are very important, the importance of the more physical existence of ground water cannot be overemphasized. Many streams and rivers would not exist without the contribution of ground water makes to the flow. On the Canadian Shield, for example, many streams are 100 percent ground water fed year-round, while others vary from 0 to 100 percent depending on the time of year and the amount of precipitation. In the prairie region, many streams would disappear during the summer months if ground water were not available to maintain their flow. It cannot be overemphasized that it is ground water which supplies the flow in streams and rivers during low flow periods and during droughts.

MONITORING OF GROUND WATER

When one accepts that ground water is a very important part of the hydrologic cycle, that it does move into the surface water system, and that its chemistry is variable, the question of how it should be monitored arises. First, the high cost of ground water monitoring, particularly the drilling and site instrumentation costs, dictates that

it must be issue oriented -- that it must address a specific need or answer a specific question. The problem is compounded by the fact that ground water flow occurs in three dimensions, not just in one (or two) as in surface streamflow. It is very difficult to obtain adequate coverage of an area which is hidden from sight and is normally not well mapped. Being issue oriented, any ground water monitoring network should have a finite life span and be subject to periodic review to ensure that it continues to address the problem at hand. Most provincial ground water monitoring networks have been installed for very specific purposes, eg. monitoring ground water levels and quality near a pumping well, and accordingly have performed well and produced the best value for the high costs involved.

Although a detailed discussion of their application is beyond the scope of this paper, it is possible to list the main factors to be considered when designing a monitoring network. First, the purpose for undertaking the monitoring must be clearly established, whether it is to determine water quality or to trace the spread of a contaminant. If monitoring the movement of a contaminant is the objective, for example, the source, the concentration, the chemical-physical properties, and the potential flow direction must be determined. Then, using these factors, the optimal coverage desired and the practical coverage possible must be reconciled, both areally and with depth. The type of sampling ports to be used, whether these are continuously screened or screened only at intervals, must be decided. The materials used in all construction must be

appropriate for the contaminant under investigation. The drilling method should add a minimum of contamination to the ground water system and allow representative samples to be retrieved. To further ensure sample integrity, the sampling materials and methods must be regularly reviewed. Using available data, a sampling frequency should be established which will permit detection of any significant trends in the chemical(s) under investigation. Finally, provision must be made to review and interpret all data, and to assess the adequacy of the installations for achieving the study's objective.

There is one additional difficulty associated with ground water sampling which is not encountered in sampling surface water. The ground water is out of equilibrium with the atmosphere and special precautions are required to obtain representative samples. In particular, pH, Eh, temperature, and dissolved oxygen must be measured in the field using a closed flow cell to exclude air prior to analysis.

SPECIAL CONSIDERATIONS IN THE NORTH

Transferring to the North technology and methods for ground water monitoring developed in the South, requires careful consideration of Northern condition. Many of these special considerations are associated with permafrost. Although it is known that permafrost does not act like concrete, and that liquid ground water does exist within it and move through it, many questions remain to be answered. The role of the active

layer, for example, and its contribution to surface water hydrology are not well understood. The quality and quantity parameters of sub-permafrost ground water have not been thoroughly investigated. This is especially true of the quality variables. In addition, because most recharge in the North occurs during the spring melt period, rather than throughout the summer months as in the South, ground water flow patterns are significantly different. Furthermore, if the amount of climate change currently being predicted (8°C over the next 50 years) occurs, the effect on the permafrost-ground water regime will be much more dramatic than the effect encountered in the South. Not only would the water quality undoubtedly be altered, but the physical layout of the whole surface water drainage system will likely be changed.

GROUND WATER, WHAT PRICE IGNORANCE?

There are several reasons that ground water has been (and continues to be) ignored in studies of water quality and quantity. The first is simply that it is out of sight, and so easier to put out of mind than a problem with surface water might be. Second, studying ground water is a very expensive proposition, and ignoring it leads to significant short term savings. Third, ground water generally moves very slowly, and problems may take years, generations, or even centuries to surface.

In the long term, these short term views of ground water contamination will result in problems which necessitate very expensive, time consuming solutions. If ground water contamination is ignored for too long, associated surface water bodies will become contaminated, and the then visible problem will have to be addressed at vastly greater cost. Once ground water is contaminated, the cleanup requires difficult, expensive, and long-term procedures. The initial expense for drilling and instrumentation prior to the wholesale spread of contamination will then appear insignificant.

Consideration of all these facts suggests that the best solution is to prevent contamination in the first place, and where this is not possible to assess the extent of the problem and act as quickly as possible to restrict the spread. The least acceptable alternative is to ignore the issue in the hopes that it will go away.

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